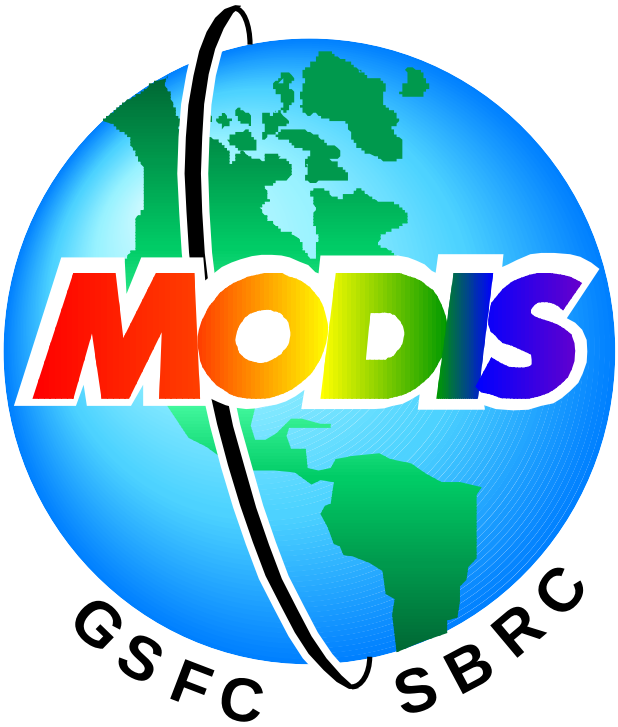
MODIS Science Team

Meeting Minutes



May 4 - 6, 1994

NASA Goddard Space Flight Center

Greenbelt, MD 20771

Prepared by Science Systems and Applications, Inc.

MODIS SCIENCE TEAM MEETING MINUTES
May 4 - 6, 1994

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LIST OF ATTACHMENTS

Note: Below is a subset of the handouts distributed at the MODIS Science Team Meeting. The complete set of handouts are not included in this condensed hardcopy; they can be obtained only from MODARCH. Two different numbering schemes were used to distinguish the two sets of handouts; those attachments included here are numbered 1-14 and those found only in the MODARCH are numbered X1-X21. If you have questions, contact David Herring at Code 920, NASA / GSFC, Greenbelt, MD 20771; call (301) 286-9515; or e-mail herring@ltpsun.gsfc.nasa.gov.

ATTACHMENTS: Included in Hardcopy

ATTACHMENTS: All Remaining

MODIS SCIENCE TEAM MEETING MINUTES

May 4 - 6, 1994

LIST OF ATTENDEES

The following persons attended the MODIS Science Team Meeting. Those flagged with "™" are MODIS Science Team Members.

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GLOSSARY OF ACRONYMS

ADEOS	Advanced Earth Observing Satellite
AGU	American Geophysical Union
AIRS	Atmospheric Infrared Sounder
APAR	Absorbed Photosynthetic Active Radiation
ARVI	Atmospherically Resistant Vegetation Index
ASAS	Advanced Solid State Array Spectrometer
ASTER	Advanced Spaceborne Thermal Emission and Reflection Radiometer
ATBD	Algorithm Theoretical Basis Document
ATMOS	Atmospheric Trace Molecule Spectrometer
ATSR	Along Track Scanning Radiometer
AVHRR	Advanced Very High Resolution Radiometer
AVIRIS	Advanced Visible and Infrared Imaging Spectrometer
BAT	Bench Acceptance Test
BCS	Blackbody Calibration Source
BOREAS	Boreal Ecosystem Atmospheric Study
BRDF	Bidirectional Reflection Distribution Function
CAR	Cloud Absorption Radiometer
CCB	Configuration Control Board
CCN	Cloud Condensation Nucleii
CCRS	Canadian Center for Remote Sensing
CDHF	Central Data Handling Facility
CDR	Critical Design Review
CEES	Committee on Earth and Environmental Sciences
CEOS	Committee on Earth Observation Satellites
CERES	Clouds and Earth's Radiant Energy System
CIESIN	Consortium for International Earth Science Information)
CNES	Centre National d'Etudes Spatiales (French Space Agency)
CZCS	Coastal Zone Color Scanner
DAAC	Distributed Active Archive Center
DADS	Data Access and Distribution System
DCW	Digital Chart of the World
DEM	Digital Elevation Model
DIS	Data Information System or Display and Information System
DMA	Defence Mapping Agency
DMCF	Dedicated MODIS Calibration Facility
DoD	Department of Defense
DOE	Department of Energy
DPFT	Data Processing Focus Team
DPWG	Data Processing Working Group
DTED	Digital Terrain and Elevation Data
ΔPDR	Delta Preliminary Design Review
ECS	EOS Core System (part of EOSDIS)
Ecom	EOS Communications
EDC	EROS Data Center

EDOS	EOS Data and Operations System
EFS	Electronic Filing System
EM	Engineering Model
EOS	Earth Observing System
EOSDIS	EOS Data and Information System
EPA	Environmental Protection Agency
ER-2	Earth Resources-2 (Aircraft)
ERS-2	ESA Remote Sensing Satellite
ESA	European Space Agency
ESTAR	Electronically Steered Thinned Array Radiometer
FIFE	First ISLSCP Field Experiment
FOV	Field of View
FTP	File Transfer Protocol
FY	Fiscal Year
GAC	Global Area Coverage
GCM	Global Climate Model; also General Circulation Model
GE	General Electric
GIFOV	ground instantaneous field-of-view
GLAS	Goddard Laser Altimeter System
GLI	Global Imager
GLRS	Goddard Laser Ranging System (now GLAS)
GOES	Geostationary Operational Environmental Satellite
GSFC	Goddard Space Flight Center
GSOP	Ground System Operations
HAPEX	Hydrological-Atmospheric Pilot Experiment
HDF	Hierarchical Data Format
HIRS	High Resolution Infrared Radiation Sounder
HQ	Headquarters
HRIR	High Resolution Imaging Radiometer
HRPT	High Resolution Picture Transmission
HRV	High Resolution. Visible
I & T	Integration and Test
IDS	Interdisciplinary Science
IFOV	Instantaneous field-of-view
IGBP	International Geosphere-Biosphere Program
IPAR	Incident Photosynthetic Active Radiation
ISCCP	International Satellite Cloud Climatology Project
ISLSCP	International Satellite Land Surface Climatology Project
IV&V	Independent Validation and Verification
IWG	Instrument Working Group
JERS	Japanese Earth Resources Satellite
JPL	Jet Propulsion Laboratory
JRC	Joint Research Center
JUWOC	Japan-U.S. Working Group on Ocean Color
LAI	Leaf Area Index
LARS	Laboratory for Applications of Remote Sensing
LTER	Long-Term Ecological Research
MAB	Man and Biosphere
MAS	MODIS Airborne Simulator
MAT	MODIS Algorithm Team
McIDAS	Man-computer Interactive Data Access System
MCST	MODIS Calibration Support Team
MERIS	Medium Resolution Imaging Spectrometer
MFLOP	Mega FLOP, or a million floating point operations

MGBC	MODIS Ground Based Calibrator
MISR	Multiangle Imaging Spectro-Radiometer
MOBY	marine optical buoy
MODARCH	MODIS Document Archive
MODIS	Moderate-Resolution Imaging Spectroradiometer
MODLAND	MODIS Land Discipline Group
MOPITT	Measurements of Pollution in the Troposphere
MOU	Memorandum of Understanding
MPCA	MODIS Polarization Compensation Assembly
MSS	Multispectral Scanner (LANDSAT)
MST	MODIS Science Team
MTF	Modulation Transfer Function
MTPE	Mission to Planet Earth
NASA	National Aeronautics and Space Administration
NASDA	National Space Development Agency of Japan`
NASIC	NASA Aircraft Satellite Instrument Calibration
NDVI	Normalized Difference Vegetative Index
NEΔL	Net Effective Radiance Difference
NEΔT	Net Effective Temperature Difference
NESDIS	National Environmental Satellite, Data, and Information Service
NIR	near-infrared
NIST	National Institute of Standards and Technology
NOAA	National Oceanic and Atmospheric Administration
NPP	Net Primary Productivity
NPS	National Park Service
NSF	National Science Foundation
OBC	On-Board Calibration
OCR	optical character recognition
OCTS	Ocean Color and Temperature Scanner
OSC	Orbital Sciences Corporation
OSTP	Office of Science and Technology Planning
PDR	Preliminary Design Review
PFM	Protoflight Model
PGS	Product Generation System
POLDER	Polarization and Directionality of Reflectances
QCAL	calibrated and quantized scaled radiance
RAI	Ressler Associates, Inc.
RDC	Research and Data Systems Corporation
RMS	Room Mean Squared
RSS	Root Sum Squared
SAR	Synthetic Aperture Radar
SBRC	Santa Barbara Research Center
SCAR	Smoke, Cloud, and Radiation Experiment
SCF	Scientific Computing Facility
SDSM	Solar Diffuser Stability Monitor
SDST	Science Data Support Team
SeaWiFS	Sea-viewing Wide Field of View Sensor
SIS	Spherical Integrator Source
SNR	Signal-to-Noise Ratio
SPDB	Science Processing Database
SPSO	Science Product Support Office
SRC	Systems and Research Center
SRCA	Spectroradiometric Calibration Assembly
SSAI	Science Systems and Applications, Inc.

SSMA	Spectral/Scatter Measurement Assembly
SST	Sea Surface Temperature
STIKSCAT	Stick Scatterometer
SWAMP	Science Working Group AM Platform
SWIR	shortwave-infrared
TBD	to be determined
TDI	time delay and integration
TDRSS	Tracking and Data Relay Satellite System
TIMS	Thermal Imaging Spectrometer
TIR	thermal-infrared
TLCF	Team Leader Computing Facility
TM	Thematic Mapper (LANDSAT)
TOMS	Total Ozone Mapping Spectrometer
TONS	TDRSS On-board Navigation System
TRMM	Tropical Rainfall Measuring Mission
UARS	Upper Atmosphere Research Satellite
UPN	Unique Project Number
VAS	VISSR Atmospheric Sounder
VIRSR	Visible/Infrared Scanning Radiometer
VIS	visible
WAIS	Wide-Area Information Servers
WWW	Worldwide Web

MODIS Science Team Meeting
May 4 - 6, 1994

SUMMARIES OF THE MINUTES

1.0 PLENARY SESSION

The MODIS Science Team Meeting was chaired by Dr. Vincent Salomonson, MODIS Science Team Leader. The meeting consisted of a general Plenary Session on Wednesday, followed by separate Discipline Group meetings on Thursday, and then attendees reconvened for a Final Plenary Session on Friday. The minutes of these proceedings were recorded by Dr. Jim Butler (Calibration Group Meeting), David Herring (Plenary and Atmosphere Group Meetings), Locke Stuart (Oceans Group Meeting), and Dave Toll (Land Group Meeting).

1.1 Welcome and MODIS Overview

Salomonson began the meeting with a note that the MODIS Logo has been finalized. He welcomed the attendees and stated that MODIS and the EOS Program are in another turbulent period. Salomonson said one of the objectives of this meeting is to provide a forum for an informal dry run in preparation for next week's ATBD (Algorithm Theoretical Basis Document) review. During the reviews, he instructed the Team to be prepared to justify why we need 36 bands, why we need quick look image data, why we need 0.3° to 0.5° sea surface temperature resolution, why we need almost daily global coverage, etc. In short, he said, we will be challenged to defend every MODIS parameter.

Salomonson reported that the need for a 15-year EOS data set has also been questioned at the highest levels. He stated that he feels that EOS must proceed in such a way as to provide observations that responsibly and rigorously document global and regional change. This means fundamentally that all instruments should be well calibrated and characterized so that results can be intercompared over time and space. It is true, for example, that if a given instrument is upgraded or changed from one model to another, the changes should be accomplished in such a way as to not compromise any time dependent trends being observed. Any changes in MODIS, made over the EOS 15-year program, or over any observing period for that matter, should keep this principle in mind.

He noted that SBRC appears to be doing their best to produce a high quality instrument and to contain costs as much as possible. He also felt that the Calibration Peer Review for MODIS was constructive.

1.2 Headquarters Perspective

Salomonson introduced Diane Wickland, co-MODIS Program Scientist, to present the headquarters perspective of MODIS. Wickland feels that MODIS is the most focused, well-prepared, and balanced of all EOS instrument teams. She stated that she is

available as a liaison between the MODIS Team and NASA HQ; she plans to help maintain clear lines of communication, answer questions, and help solve problems.

Wickland reported that she was involved in the FY94 budget discussions with Congress. She stated that the MODIS Team needs to begin planning future budgets so that they may respond to possible cuts in a way that is thoughtful and responsive to priorities across the board. She concluded that she is impressed with MODIS' development of ATBDs.

Frank Muller-Karger, co-MODIS Program Scientist, said he is also concerned about the future budget process for MODIS. He is unsure where the budget cuts will end so he wants to make sure the MODIS Team interacts with the other EOS instrument teams so that MODIS may clearly state how it needs the other sensors—particularly EOS COLOR. Specifically, EOS COLOR has features that MODIS does not have. Do we want them, do we need them, and where will they fit in? Muller-Karger reported attending the MERIS Team Meeting and stated that the MODIS Team needs to interact with MERIS.

Muller-Karger announced that the SeaWiFS launch date will probably slip from Sept. 30, 1994, to January 1995.

1.3 EOS Project Science Report

Michael King stated that he would not present any EOS budget figures because they seem to be changing on an almost daily basis. He reported that depending upon the budget, there may be some additional slips in launch schedules of EOS spacecraft (See Attachment 2). There may be delays in the launch of EOS AM-2, ALT, and Chemistry-1 of up to 9 months. The launch of EOS COLOR will necessarily slip to match the SeaWiFS slip.

King announced that the Interdisciplinary Working Group (IWG) may expand to include all EOS Science Team members, as well as IDS co-investigators.

King stated that information on the EOS Project is now available on the World Wide Web (WWW)—*The Earth Observer* is there, as are the EOS Science Calendars, *EOS Reference Handbook*, and the EOS Directory.

Regarding ATBDs, King reported that all but one have been submitted. Five reviewers per ATBD were solicited, however, comments were received from an average of 2 or 3 reviewers on about half of the ATBDs. He hopes to make the ATBDs available on WWW after the reviews and subsequent revisions. The Science Product Support Office (SPSO) is currently examining the ATBDs to determine whether changes in the requirements are needed. The SPSO will distribute a revised spreadsheet containing the rescoped processing requirements.

1.4 EOSDIS Status Report

H.K. Ramapriyan (Rama) stated that EOSDIS consists of several components—ECS (EOSDIS Core System), EDOS (EOS Data and Operations System), IV&V (Independent

Validation and Verification), and Ecom (EOS Communications) (See Attachment 3). The Ecom system design review was held in February.

Rama stated that a working prototype of the version 0 processing software for the DAACs will be released in July 1994. Representatives from among all user groups will serve as "tire kickers" for the software. A system design review is scheduled for June 1994. Online documentation is being made available on the WWW.

1.4.1 EOSDIS Project Scientist Presentation

Steve Wharton gave a summary of his ongoing activities (see Attachment X1). He has attended a number of cross organizational meetings to facilitate communication of relevant issues and action items. EOSDIS Project Science is staffed by 1 1/2 personnel—himself half time, Bob Lutz full time, and Monica Myers three-quarters time.

Regarding Science Data Processing, Wharton stated that the current requirements are believed to exceed the current EOSDIS budget for hardware. There is a need to link processing requirements to cost. Also, there is growth uncertainty surrounding the EOS processing requirements, for which there is no management plan. He feels that the ATBD review will help identify who will process what data and who will provide ancillary data. Wharton also reported that there is insufficient information on the PGS (Product Generation System) Toolkit performance.

Wharton stated that there needs to be greater coordination between the Science Teams, EOSDIS Project, and Hughes. There needs to be a clear understanding of which EOS products EOSDIS will provide interfaces for, and which products will be supported at the DAACs. He said there needs to be a schedule for the phase-in of post-launch products. The Goddard DAAC is implementing support teams to facilitate this phase in.

Salomonson noted that EOSDIS has MODIS' processing requirements listed at 410 MFLOPS, whereas the actual project requirement is several GFLOPS. He asked how EOSDIS plans to resolve this discrepancy. Wharton responded that he is awaiting cost information and a processing "envelope" for which EOS Project will commit resources. In short, he said, he needs a processing baseline and a clear understanding of cost.

Bob Evans added that the Science Team needs an idea of the cost per processing unit. He is aware of a number of alternatives for meeting the processing requirements by launch. He pointed out that if team members were aware of EOSDIS' costing methods, then they could better address processing concerns.

1.5 MODIS Project Report

Richard Weber gave a brief status summary of MODIS Project issues. SBRC has implemented descoping options to control costs; more descopes are under consideration. Weber stated that there are cost overrun concerns—whereas the original proposed cost for building three MODIS instruments was $180 million, the projected cost is now exceeding $200 million. The EOS AM Project has asked SBRC to develop a cost reduction and control plan, which they will submit later this month. Meanwhile,

Weber stated, the AM Project and Science Team must add no new capabilities or requirements for MODIS. He reported that an audit of SBRC was conducted by the GSFC comptroller—SBRC's cost projections were validated.

Weber reported that SBRC will assemble and test the MODIS engineering model (EM) over the next seven months. So far, the SBRC's technical performance has been solid; however, the EM will not include the corrections for the ghost image problem—those fixes will be implemented in the protoflight model. Weber announced that the electronics breadboards are complete as is the beryllium structure.

Weber presented a list of the top concerns facing MODIS (See Attachment 4). He announced that in order to save money, SBRC will reuse some of the EM parts on the MODIS prototype. The only OBC (on-board calibrator) on the EM will be the blackbody. SBRC is about 2 to 3 months behind schedule. Weber stated that the scan mirror is a possible source of vibrations, so SBRC must thoroughly test its rotation. He said there is a new problem of scattered light coming off the scan mirror. This problem was unexpected because the mirror meets all specs.

1.5.1 SBRC Reports

Weber introduced Tom Pagano, who delivered the SBRC report (see Attachment X2). Pagano stated that MODIS is a complicated instrument and has proven more difficult and costly to build than originally thought. In order to save money, SBRC will use EM hardware on the protoflight model, and will attempt to complete the EM early in order to reduce cost, reduce risk, and preserve the protoflight schedule. Pagano stated that SBRC will not build an SRCA, solar diffuser, or SDSM (solar diffuser stability monitor) for the EM because they are not critical to its functionality. These shortcuts will allow SBRC to get test data sooner and begin devising any necessary fixes. In short, Pagano said that in about 7 months SBRC will have built a fully functional MODIS EM.

Pagano showed an informal video presentation on the mechanical assembly, optics development, electronics development, and system integration of the EM. He concluded that high performance margins are being maintained by SBRC and specs are being met. Subsystem and ambient testing will begin in December 1994 and polarization and scan mirror test results should be available in January 1995.

1.6 MCST Calibration Update

Bruce Guenther, acting head of MCST, presented the MCST calibration update. He began by clarifying the relationship between Phil Slater, MODIS calibration scientist, and MCST—Slater is the primary reviewer of MCST activity. Harry Montgomery is the head of MAT (MODIS Algorithm Team).

Guenther reported that MCST has rescoped its core Level 1B algorithm for PGS processing. MCST will also develop an auxiliary algorithm, that is not part of its Level 1B algorithm for SCF processing, for analyzing the bowtie effect of overlapping pixels. Guenther stated that MCST will not do masking, nor will it resample or replace dead pixels. Masking algorithm development has been reassigned to Paul Menzel.

Regarding risk assessment, Guenther said he expects to have little or no validation of the calibration in the emissive IR bands, other than the Level 2 products. MCST issued a consensus statement on lunar viewing, which Guenther distributed (see Attachment 5).

1.6.1 MODIS Bowtie Effect

Steve Ungar gave a presentation on the bowtie effect in MODIS. He showed a viewgraph representing two adjacent swaths (see Attachment 6). Ungar explained that, as the spacecraft moves forward, the MODIS detector 1 of 10 detector array will, at two positions each swath, observe the same piece of ground that detector 10 viewed on the previous swath. Ungar stated that MCST can exploit the bowtie effect to determine how well calibration is performed. For example, differences in optical properties of the scan mirror surfaces can be determined, detector-to-detector calibration can be performed within a band, and system misalignments can be examined. Ungar also said that since detector 1 coverage overlaps both detectors 9 and 10, MCST will have the ability to derive the relations between detectors 9 and 10. Ungar also made handouts available explaining the MODIS plan for within-band detector-to-detector calibration with MODIS Earth view data (see Attachment X3).

Ungar showed an AVHRR image of the U.S. west coast. He then showed that same image as it would be seen by MODIS by simulating the bowtie effect.

1.7 SDST Status Report

Ed Masuoka reported that SDST will deliver beta software to EOSDIS in June 1995. In January of this year, they received heritage code from the Science Team. According to Masuoka, there were some problems with the code; he stated that SDST prefers test data in ASCII format rather than binary. SDST expects to receive "MODIS-like" software from team members in October 1994 which uses a number of MODIS channels. By April 1995, SDST hopes to be able to integrate all MODIS software end-to-end. For the next beta software delivery Masuoka said he would like to see PGS Toolkit I/O (input/output) functions already incorporated. He noted that the team must adhere to ECS Project's software standards. He told the team that an e-mail letter is forthcoming discussing the code for which each member is scheduled for delivery. See Attachment X4.

1.7.1 Prototyping

Masuoka stated that SDST plans to facilitate development and integration of MODIS science software by providing operations support in a computing center set-up to process large data sets; assembling and co-registering data sets, providing programming support to integrate software; and participating in cooperative efforts with MODIS Teams, pathfinders, DAACs, ECS Project, and HAIS (Hughes Applied Information System).

1.7.2 EOSDIS Data Processing Focus Team (DPFT)

Masuoka announced that the PGS Toolkit has been delivered; IV&V will take 2 weeks to complete. Then SDST will distribute the Toolkit.

1.7.3 Simulated Data

Al Fleig presented SDST's perspective on simulated test data and gave an overview of their work so far (see Attachment X5). He explained that they will perform two tests on the data—science and code tests. Science tests include testing of both individual algorithms and connected algorithms. Code tests consist of single algorithms, MODIS processing strings, MODIS end-to-end processing, and EOSDIS end-to-end processing. Fleig noted that EOSDIS end-to-end processing will be a difficult test to conduct and is not part of SDST's current budget.

SDST's approach to code testing will involve using real data provided by Science Team members and converting it into a format that will be used by MODIS. According to Fleig, SDST will do the work, but they need input from the Science Team as to what data to test. He noted that if the strings of code work, then the end-to-end tests will be primarily code tests. He stated that there are some opportunities to find some channels from other data sets that are like MODIS.

1.7.4 Synthetic Data

Fleig said he is convinced that MODIS will need some synthetic data for testing, but he doesn't yet know how it will be obtained. So, he solicited advise from the Science Team as to what synthetic data they will need to test their algorithms or code strings, and how SDST can help. Fleig stated that SDST is willing to produce synthetic data sets, but that could be a budgetary black hole so such an undertaking must be planned carefully. He noted also that he is not sure how to test the throughput from Land to Cloud algorithms.

1.7.5 Geolocation

Fleig introduced Robert Wolfe, who has succeeded Jim Storey in taking the lead on developing a geolocation algorithm. Wolfe stated that there is some concern that geolocation accuracy degraded for the EOS PM-1 spacecraft (see Attachment 7). He said that EOS Project has eliminated the requirement for TDRSS downlink and there is concern that this will result in a loss in tracking capability. The EOS PM-1 Project has stated that they plan to continue TDRSS contact for tracking; however, they do not plan to use TONS (TDRSS On-board Navigation System) for tracking. Tracking will be done on the ground with a higher accuracy and ephemeris will be done with at least as high an accuracy as for EOS AM-1. Wolfe said he sent a memo to EOS Project explaining his concern that random error and pointing knowledge must be less than 0.1 pixel at nadir.

Wolfe reported that SDST's approach in meeting the Science Team's accuracy requirements is to perform dead reckoning by using real-time ephemeris and attitude to calculate geolocation information for each spatial element.

1.8 Land Science Presentations

1.8.1 Snow Mapping Efforts and Error Analysis

Dorothy Hall gave a presentation on her efforts to map the temporal and spatial variability of snow on hemispheric, continental, and large watershed scales (see Attachment X6). She explained that her product will be a 7-day composite of the

maximum snow cover at 1-km resolution. Using band 6, MODIS can discriminate between snow and clouds. Global-scale snow cover maps are used to extend and improve estimates for climatological studies and as input to GCMs (global climate models). Regional-scale maps are used as input to hydrological models to improve runoff prediction and are useful for predicting water supply and flooding.

Hall showed samples of NOAA weekly hand-drawn snow cover maps showing the variability of snow in the northern hemisphere. She reported that there was a decrease in snow cover in the 1980s. She also showed passive microwave data—of glacier ice, sea ice, and snow—which can be acquired almost daily. She hopes to fine-tune her algorithms by comparing them to existing data sources; however, there are problems inherent in existing snow data sources. Moreover, she explained that mapping snow cover is difficult in cloud covered scenes, mountain shadows, and dense forest cover.

Hall showed her prototype algorithm, which uses TM (Thematic Mapper) bands 2, 4, and 5. She has achieved accuracies of greater than 95 percent over a small test area.

Steve Running asked if Hall is correcting for topography in forested areas. He stated that whenever neighboring slopes are obviously snow-covered in the sun, then one can assume the shaded areas nearby are snow covered. One can also guess intuitively from temperature derivations. Hall stated that NOAA makes these assumptions in generating their maps.

Hall concluded that MODIS snow maps will represent a substantial advancement due to improved spectral and spatial resolution, as well as its ability to map snow automatically. Her future activities will focus on error analysis and in refining the SNOMAP algorithm using MAS data.

1.8.2 Global Topography: Options for MODIS

Jan-Peter Muller began his presentation (Attachment X7) with the statement that the Land Group needs digital elevation models (DEMs) for all activities that MODIS products will be applying to. He said MODIS needs three to five grid points per pixel in order to calculate terrain slopes—a 0.5-km grid is more than sufficient. Muller stated that DEMs are required for both conducting science (such as on global circulation models, hydrological cycles, carbon cycles, and sulfur cycles) and generating satellite geophysical products (such as geometric and radiometric calibration and surface bidirectional reflectance retrieval). He showed a list of specific topography requirements for MODIS .

Muller stated that there is no single-source solution for the supply of a global DEM at the 100-m resolution required for MODIS land processing. There are a number of options which require further investigation of costs and problems of data supply. He feels that MODIS should emphasize the importance of this global DEM product being provided by EOSDIS/ECS and NOT by individual instrument teams. Finally, the options presented suggest that with sufficient financial backing (e.g. through a Pathfinder project) and/or support from other space agencies or other U.S. Federal Agencies (particularly DoD/DMA), a global DEM product is achievable before launch.

1.9 Atmosphere Science Presentations

1.9.1 Cloud Properties

Liam Gumley gave a presentation on the multi-sensor remote observations of thin cirrus clouds during the FIRE Cirrus II campaign (see Attachment X8). He explained that thin cirrus clouds have important radiative effects on remote sensing; for example, atmospheric corrections. Cirrus clouds are difficult to detect because they have low reflectance and low temperature contrast. For the FIRE Cirrus II campaign, a combination of sensors was used aboard the ER-2 aircraft—MAS, HIS (a nadir-viewing IR interferometer), and CLS (a nadir pointing lidar)—to study the sensitivity and spatial resolution required to detect thin cirrus clouds.

Gumley concluded that a single instrument is not sufficient for cirrus cloud detection, and that VIS, NIR, and IR information are all useful in tandem. For the MODIS cloud mask approach, he recommended using field observations from multiple sensors. He also encouraged the development of robust detection / classification methods for thin cirrus that will allow for the correction of thin cirrus.

1.9.2 Cloud Retrievals

Steve Platnick gave a presentation on the uncertainties in the retrieval of optical thickness and droplet radius for liquid water clouds (see Attachment X9). He explained that optical thickness and effective cloud droplet radius are the major cloud parameters for determining current, and future, cloud energetics / forcings; processes in cloud development; and parameterizations for GCMs (general circulation models). Platnick stated that the desired accuracy for determining optical thickness and effective radius of droplet size depends upon your application. He noted that the 1.6-µm band is good for measuring effective radius, as are the 2.2- and 3.7-µm bands. MODIS is special because for the first time these three channels will be included on the same platform.

1.9.3 Aerosol Size Distribution

Yoram Kaufman began his presentation by defining "aerosols" as solid or liquid particles suspended in air. Kaufman gave size distributions of some common atmospheric aerosols (see Attachment X10). He stated that it is important to understand the aerosol size distribution because that helps scientists understand the magnitude of aerosol radiative forcing (e.g. convection and climate cooling) and how it affects cloud condensation nuclei (CCN's), atmospheric chemical reactions (such as ozone depletion), and remote sensing of land and oceans.

Kaufman showed sample measurements taken during the SCAR-A campaign. He noted that with the increase in optical thickness there is a corresponding increase in sulfate aerosol particle radius; and salt aerosol particle radius increases proportionally to sulfate particles. The SCAR-A *in situ* measurements validated the image data.

Kaufman presented graphical data which show that phase function depends upon particle size. He and Didier Tanré published an article on the subject in *Nature*. Over the ocean, Kaufman will derive the aerosol size distribution from the spectral dependence of the radiance as derived from MODIS data; this will be validated using

ground based remote sensing data from sun/sky radiometers. He stated that it will be difficult to derive aerosol size distribution over land. He plans to use not only MODIS, but a combination of data from different instruments in tandem—MODIS will give spatial distribution and ground-based information will give size distribution and a combination of the two will yield the total characteristics of atmospheric aerosol globally.

Kaufman introduced Lorraine Remer, who discussed the advantages to using both MODIS and Cimel's sun/sky photometers. Remer stated that whereas MODIS will give better global coverage, the sun/sky photometers yield smaller spatial coverage. Chris Justice asked if the development of the ground-based network of sun/sky photometers is a grassroots effort; and if so, how will we ensure that it is maintained and carried forward? Remer responded that although there are encouraging signs recently, there is no long-term commitment to the maintenance of the network. Justice asked if there have been discussions of any agencies taking the lead on maintaining the network. Remer responded negatively.

1.10 Oceans Science Presentations

1.10.1 Sea Surface Temperature

Otis Brown gave a presentation on the role of sea surface temperature (SST) in climate change (see Attachment X11). According to Brown, SST is the primary mechanism for communicating the ocean upper layer thermal state to the atmosphere, affecting both weather and climate. Scientists first began using satellites to measure sea surface temperature back in the late 1960s. Today, we can retrieve SST globally to within ±0.5°C. However, we still do not have a long-term global data set. Using Nimbus HRIR (High Resolution Imaging Radiometer) data, SST error was around 2° RMS (root mean squared); whereas MODIS will have only 0.3° RMS. Buoys will be used to validate MODIS data—there are currently about 400 buoys in the oceans collecting *in situ* data, and Brown expects there will be around 900 by launch.

According to Brown, the approach to developing the MODIS SST algorithm will be to examine AVHRR data retrievals, perform radiative transfer modeling, cross-validate the model and *in situ* data, transfer AVHRR results to MODIS, perform *in situ* algorithm development observations, and conduct post-launch *in situ* comparisons.

Bob Evans presented the Oceans Group's methodology for establishing a processing framework and match-up database for using AVHRR GAC (global area coverage) data to derive products for testing their MODIS Ocean hypotheses (see Attachment X12). He stated that their goals are to implement a database with satellite, in situ, and ancillary data for vicarious sensor calibrations, and to validate algorithm products.

Evans reported that the Oceans Group has redefined the "data day"; 24 hours in a sun-synchronous orbit typically ends and begins over the middle of the Pacific Ocean. He has computationally matched *in situ* with satellite data and created a match-up database.

Evans gave an overview on the data volume requirements for storing and processing MODIS Oceans data. He stated that the total volume requirements will be about 50 Gbytes per day. The processing requirement for water-leaving radiance computations and SST will be about 92 MFLOPS.

2.0 ATMOSPHERE DISCIPLINE GROUP MEETING

The MODIS Atmosphere Discipline Group Meeting, held on Thursday, May 5, at the Greenbelt Marriott, was chaired by Michael King. Present were Paul Menzel, Kathy Strabala, Bo-Cai Gao, Si-Chee Tsay, Steve Platnick, Yoram Kaufman, Lorraine Remer, Liam Gumley, Simon Hook, Menghua Wang, Patricia Henderson, and David Herring.

2.1 Joint MODLAND/Atmosphere Group Discussion of SCAR-C

Initially, the Atmosphere Group convened jointly with the MODLAND Group to discuss the upcoming SCAR-C field campaign. This discussion is summarized in Section 4.1.

2.2 ATBD Peer Review Discussion

Following the meeting with MODLAND, the Atmosphere Group reconvened in the Patuxent Room. King stated that the focus of the meeting would be on the ATBD Peer Review Process, which he feels is a positive and constructive experience. King explained that at the Peer Review each Science Team member will deliver a 20-minute presentation for each of his or her algorithms. He noted that each member of the Atmosphere Group has delivered real beta test code to SDST.

In order to prepare strategies for the Atmosphere Group's presentations, the group discussed the anonymous peer reviewers written comments on their ATBDs and how the group might respond to those comments. King stated that on the last day of the oral peer reviews, the panel will convene to formulate summary recommendations for each Instrument Team. During the oral peer review, King explained that, in the interest of time, questions will be restricted primarily to panel members. The audience can, however, submit written questions later.

For the anonymous written peer reviews held prior to the MODIS Science Team Meeting, King explained that an average of five reviewers were selected for each ATBD, based on recommendations of the authors, together with suggestions from the discipline leaders.

2.2.1 Fire ATBD Anonymous Peer Review Comments

Kaufman gave a summary report on his ideas for developing a Fire algorithm and the peer reviewers' comments on his Fire ATBD. He stated that fires have a direct influence on the atmosphere. The basic idea behind his algorithm is to try to detect fires from space. His product will show the geographic distribution of fires and where deforestation occurs as a result. He hopes to be able to differentiate between smoldering, and flaming fires. He plans to use the 3.95 μm and 11 μm MODIS channels during the night and add the 1.65 μm during the day.

Kaufman said that the Fire algorithm that he and Justice developed is still theoretical. Menzel said he reviewed the Fire ATBD and congratulated Kaufman on an excellent effort. Overall, Kaufman concluded, the peer reviewers comments were positive.

2.2.2 Aerosol ATBD Anonymous Peer Review Comments

For remote sensing of aerosol, Kaufman explained that there is a huge, ongoing international effort to study biomass burning using aerosol as a tracer for trace gases. Over oceans, aerosol has a wide spectral signature that allows for the derivation of size distribution. Kaufman plans to use the 1.38-µm MODIS channel and SAGE (Stratospheric Aerosol and Gas Experiment) data to detect stratospheric aerosol . He also plans to collaborate with others (Holben, Frouin, Prospero, Karnieli, Raes and the MODIS Oceans Group members) to construct a land network of photometers for validation, measurement of certain parameters (such as phase function and size distribution of aerosol particles), and development of more dynamic models.

In his efforts so far Kaufman has concentrated on the "dark target" approach, which he plans to study as an at-launch approach for deriving his aerosol product over land. Over the ocean, Tanré and Kaufman will derive the aerosol size distribution from the MODIS spectral radiances. Kaufman reported receiving feedback from two reviewers—an "A" and a "B".

2.2.3 Water Vapor ATBD Anonymous Peer Review Comments

Gao summarized his ongoing development efforts on the water vapor product, for which he plans to use the 0.86-µm and 0.94-µm MODIS channels. Gao explained that MODIS will detect total atmospheric water vapor integrated from the surface to the top of the atmosphere.

Kaufman added that the reviewers comments on this ATBD were "B"s. Gao and Kaufman published a paper on this algorithm.

2.2.4 Cloud Product ATBD Anonymous Peer Review Comments

King stated that Si-Chee Tsay and Steve Platnick did an enormous amount of the work on his Cloud Product ATBD. The MODIS Cloud Product, he explained, is really one product combining several parameters from both his and Menzel's algorithms. However, he and Menzel wrote two separate ATBDs; King's is concerned with particle radius and optical thickness. Code testing and validation efforts for the cloud product have focused on the VIS through the 2.16-µm channels, and have included the 3.7 µm band in a separate algorithm. Plans are to combine these two complimentary approaches into a single algorithm.

King sent his ATBD to four reviewers and received comments from only two. One reviewer commented that in his algorithm King needs to pay additional attention to surface effects on cloud retrievals. King also said he is aware of the ongoing need for validation of his algorithm.

Platnick asked if there are funds set aside within EOS for post-launch validation campaigns. King responded negatively.

2.2.5 Cloud Mask ATBD Anonymous Peer Review Comments

Menzel reported that he is collaborating with the CERES Team (Bryan Baum and Ron Welch), John Barker, Steve Platnick, and Al Fleig in developing the MODIS Cloud Mask algorithm. Menzel said the MODIS Cloud Mask borrows from the heritage of the ISCCP cloud mask, the new AVHRR cloud mask algorithm (CLAVR, now used in the AVHRR pathfinder activity), in addition to ongoing work in spatial coherence. The ATBD was written by Steve Ackerman, Kathy Strabala, and Paul Menzel, with contributions from Ron Welch and Bryan Baum of the CERES Team.

According to the anonymous reviewers, Menzel's ATBD is an excellent first cut, but the algorithm "needs to evolve". Missing is an implementation plan as well as a plan for validation. The implementation plan will contain inputs from several EOS scientists, but amalgamation of those inputs will be the responsibility of the University of Wisconsin. Menzel said he needs a liaison like Liam Gumley to help him integrate the Cloud Mask into the TLCF (Team Leader Computing Facility). Also, there needs to be an explanation of how the software will be written and how that software will be integrated with CERES' software in the TLCF. Menzel said he expects the cloud product output to be rather large—24 bits per IFOV (Instantaneous Field of View). Currently, the algorithm is missing a quality flag; he noted that a fuzzy logic algorithm could be incorporated for a quality flag. Menzel stated that he is confident MODIS will have the best cloud mask ever developed due to the many channels and high spatial resolution available on MODIS, as well as its many calibration and validation checks and balances.

Menzel observed that many of MODIS' VIS algorithms need to be tuned to ecosystems. He plans to evolve the Cloud Mask algorithm as ecosystems are identified.

2.2.6 Cloud Top Properties ATBD Anonymous Peer Review Comments

Menzel said his Cloud Top Properties algorithm is a modification of the HIRS climatology heritage. Menzel is in the process of establishing ten to fifteen databases on global cloud cover, including high thin clouds. Reviews of this ATBD were very positive.

2.2.7 Ozone ATBD Anonymous Peer Review Comments

Menzel stated that his algorithm for deriving total ozone content is not yet mature. This product has been requested by the MODIS Oceans Team as well as by ASTER. The accuracy of ozone determination with MODIS is not high, due to an inadequate source of information of stratospheric ozone and temperature. The heritage for his temperature and moisture profiles algorithm comes from VAS as well as HIRS for the IR channels. For deriving moisture distribution—horizontal and vertical—MODIS isn't doing anything new, but would enable studies of moisture structure at a much higher spatial resolution than previously available using IR sounders such as VAS and HIRS. Water vapor and temperature soundings are being derived at the request of MOPITT.

2.3 Beta Software Delivery

Menzel announced that his team has developed beta software making extensive use of McIDAS (Man-computer Interactive Data Access System), which enables data to be

pulled in from many sources. He noted, however, that McIDAS isn't compatible yet with EOSDIS' requirement for using HDF (Hierarchical Data Format).

2.4 Summary

The Atmosphere Group feels good going into the ATBD Oral Peer Reviews. King stated that there needs to be further discussion and logistics planning for SCAR-C. If MAS is flown aboard the C-130 during the BOREAS field campaign, it will need to be reconfigured and its preamps reset prior to flying aboard the ER-2 for the SCAR-C campaign.

2.5 Action Items

None.

3.0 CALIBRATION DISCIPLINE GROUP MEETING

The MODIS Calibration Discipline Group met in a single session during the Science Team meeting. The meeting was chaired by Phil Slater of the University of Arizona. Meeting minutes were acquired by Jim Butler of NASA/GSFC's Code 925.

3.1 MODIS Algorithm Team (MAT) Questions to SBRC

Tom Pagano of SBRC provided answers to a number of questions submitted to him before the meeting by the MAT (see Attachment 8). The following summarizes Pagano's answers to those questions.

3.1.1 General Questions

Concerning the lack of a reply by SBRC to a series of questions arising from the Calibration Teleconference, Pagano stated that his formal response was delayed due to intense activities surrounding the replan. Pagano assembled responses from SBRC personnel and submitted these responses to the head of MAT, Dr. Harry Montgomery. Pagano anticipates there will not be a formal reply to these questions, but a good deal of the answers will be found in the test plans and the calibration procedures. These will present information on the equipment and procedures to be used, the test results, and the software used in data reduction. Pagano also stated that the algorithm documents 151868 and 151869 which outline the plans for data reduction will be revamped.

Concerning the details on engineering telemetry data, Pagano stated that Harry Montgomery and Ed Knight have received this information. According to Pagano, MODIS has 330 telemetry points of which 140 are configuration points and 100 are temperature sensors. SBRC grossly underestimated the number of these points. Marvin Maxwell cautioned SBRC to set aside a sufficient margin for possible future growth.

3.1.2 Spectroradiometric Calibration Assembly (SRCA) Questions

Concerning whether the reference SiPd output will be included in the telemetry during spatial and radiometric modes, Pagano stated that it will be included in the telemetry in both modes.

Concerning the lamp conversion efficiency given in SBRC memo PL3095-Q03202, Pagano stated that the most current data will be used.

Concerning the equations for operating the SRCA which have not been presented in CDRL 404 or in other memos, Pagano stated that Oscar Weinstein has been working toward providing GSFC with the SRCA computer models. Montgomery recommended that Nianang Che and Eric Johnson get together for one hour to get these models straight. Pagano then recommended that Che travel to SBRC for this purpose. Pagano added that Johnson is currently working only half time on calibrators, and he recommends that people trickle out to SBRC to ask questions rather than show up in one large group. Che remarked that the SRCA spectral calibration looks overly optimistic.

Concerning the cutoff wavelength of the SiPd detector, Pagano stated that this detector cuts off at 1 micron. SWIR bands will be calibrated preflight and will not have the benefit of the SiPd as a on orbit monitor. Pagano speculated that there may be a way of extrapolating the SiPd results out to the SWIR. Marvin Maxwell pointed out advantages of placing the order sorting filter at the exit slit of the SRCA rather than the entrance slit. This would permit detection of other light orders.

3.1.3 Solar Diffuser (SD) and Solar Diffuser Stability Monitor (SDSM) Questions

Concerning the 120 seconds of calibration time provided by the SD/SDSM, Pagano stated that the view factors are designed to provide 120 seconds of calibration time taking into account seasonal variations. Pagano stated you will always get at least 120 seconds of calibration time using the SD/SDSM.

Concerning the usage frequency of the SD/SDSM being limited by thermal and power constraints, Pagano pointed out that opening the solar diffuser door constitutes a thermal transient. However, he feels that contamination could become a problem faster than the thermal transient problem. John Barker inquired whether the door could be kept open for one orbit. Pagano answered yes. Marvin Maxwell remarked that if the thermal transient is a problem it should be tested preflight. Barker added that historically, contamination on diffuser panels has been UV related.

Concerning the SBRC BRDF facility, Pagano stated that the facility is up and running from 0.4 to 2.5 microns.

Concerning whether the BRDF studies take into account the effects of different footprints on the diffuser, Pagano stated that the purpose of the SDSM is to monitor the diffuser and is designed to look at as much of the diffuser as possible. Problems will arise if the diffuser degrades nonuniformly. Che inquired if SBRC has considered the effect of potential specular changes to the diffuser inflight. Pagano stated that they anticipate no specular changes inflight to the diffuser.

The further consideration of additional MAT questions was suspended to the end of the session with the arrival of Phil Slater.

3.2 Preparation for Calibration ATBD Meeting

Phil Slater discussed what should be presented at Tuesday's Calibration ATBD review (see Attachment X13).

3.2.1 Calibration Plan Versus Calibration ATBD

Slater pointed out that the MODIS Calibration Plan discusses how the measurements will be made with little information on how the data will be combined and treated. Slater also pointed out that the ATBD appearing in the plan as Appendix A is weak.

3.2.2 Criticisms

Slater pointed out that there is no Level 1 production plan, no Level 1 ATBD, and no information on the affect on calibration of future budget cuts. Slater expressed concern over budget cuts potentially affecting the calibration inputs available at launch. Bill Barnes stated that the major criticism of the calibration plan by the peer review panel was that the plan did not tell the panel how the MCST/MAT were going to get to their goal. Bruce Guenther pointed out that the problem was a question of focus.

3.2.3 Continuing Concerns

Guenther stated that we must not simply regurgitate our concerns to the ATBD review panel but must also provide answers. Slater stated his concerns, the first of which is the absence of a system checkout of the SD/SDSM or the SRCA for the engineering model. Also, the lack of infrared transfer radiometers is a concern in that relying solely on indirect measurements of the blackbody is a risk. Slater also stated that we will not reliably know the relative accuracies of the calibration methods until three months after launch. Another concern is that the protoflight model preflight characterization of the on-board calibrators will not be completed until April 1996. Pagano expressed a concern surrounding the potential effects of scattered light off the diffuser. In order to examine this, SBRC plans to set up a surrogate SD/SDSM and place it into the engineering model for testing. It is hoped that this will enable SBRC to characterize this effect without having to build up the full flight hardware. Slater's last concern was the lack of input and participation from the Science Team concerning thermal calibration.

Guenther presented a series of charts outlining the features of the on-board calibrators (see Attachment X14). Guenther recommended that something similar to these charts should be presented at the ATBD review. Guenther maintained that this is necessary to outline to the review panel how the Level 1 products relate to the requirements and how the calibrators will enable the products to be generated and the requirements to be met. Barnes stated that the major question which must be answered is why do you need these calibrators and what would be the impact on MODIS if one of the calibrators is lost. Guenther added that the charts presented at this meeting would be accompanied by equations when presented to the ATBD review panel. Slater stated that the charts might be better presented to the review panel in handout form.

Regarding Guenther's chart on spatial registration, Marvin Maxwell was puzzled on how one can obtain better knowledge of spatial registration on-orbit than preflight. Barker pointed out that the numbers on the chart are three sigma numbers, and geolocation information should be added to the chart to convince the panel that we will

be able to do change detection. Maxwell inquired what is meant by on-orbit control. Guenther responded that it corresponds to the ability of MODIS to change cross track sampling between focal planes in the software. Maxwell also pointed out that if the SRCA fails, on-orbit location and registration can still be performed using clouds and the moon, but it cannot be done as well as with using the SRCA. Stuart Biggar emphasized that you must have capacity in the PGS to recover from hardware failure. Biggar stated that the failure of any of the on-board calibrators must be reflected in the calibration algorithm. Biggar added that all other ATBDs address the potential failure of their on-board calibrators. Guenther responded that the operational algorithm does not include the possible failure of on-board calibrators, and there is no plan to include exception handling in the PGS.

Regarding the chart on spectral calibration, Barker stated that spectral calibration should be changed to spectral characterization. Both Pagano and Slater suspect that the 0.5 nm specification for wavelength is a one sigma number. Pagano stated that the at-launch wavelength knowledge could be 0.3 nm, but this should be verified with Jim Young. Pagano stated that the wavelength knowledge will be better on orbit.

Regarding the chart on radiometric calibration, Mike Roberto stated that the band 21 specification is not officially in the specs. Pagano stated that bands 31 and 32 have a fire radiance level associated with them. Pagano added that the anticipated at launch knowledge will be 4 percent and will be wavelength dependent. Pagano stated that Jim Young thinks they will meet the 2 percent reflectance specification at launch. Both Guenther and Slater responded with doubts concerning meeting the 2 percent specification at launch without using preflight solar radiation-based calibration.

3.3 Infrared Cross Calibration

Paul Menzel of the University of Wisconsin presented plans for cross calibrating infrared instruments. Menzel started by stating that the infrared community would like to see infrared testing of MODIS in vacuum and the actual counts-to-radiance conversion techniques that will be used. Menzel stated that infrared cross calibration is important, and the infrared community will know a lot more in the next six months with the GOES instrument. The plan is to cross calibrate GOES I with GOES/VAS and HIRS. Additionally, the MAS and HIS instruments will be used in the future. Menzel stated that the MAS instrument is experiencing a problem with wavelength shifts due to temperature changes. HIS will enable a correlation between interferometric and spectrometric data. Menzel stated that without a knowledge of the spectral response, infrared calibration becomes difficult. It is anticipated that HIRS III will be ready in the MODIS time frame and there will be plenty of opportunities for cross calibration. Menzel stated that the radiance at the top of the atmosphere will be provided by a number of instruments. Menzel thinks 0.5 degrees at the top of the atmosphere is possible, with a goal of 0.3 degrees.

3.4 MODIS Out-of-Field Response: Ghosting, Crosstalk, and Scan Mirror Scatter

Pagano presented the following information on MODIS out-of-field response (see Attachment X15). With respect to the different components that contribute to the stray

signal, Pagano showed the effect in the response of SeaWiFS scanning a six-pixel wide slit across the focal plane array. Pagano's transient response specification numbers were stated as being 1 sigma numbers. Pagano's extinction ratios were stated as being integrated numbers. With respect to the worst case stray light situation, Pagano said the numbers presented were a function of cloud size, with big clouds posing a bigger effect than small clouds. Barker asked what the stray light effect would be if the cloud was detected by a strip of the focal plane. Gene Waluschka stated that to a first order approximation, the assumption of bilateral symmetry in the stray light works. To a higher order, you will see ghost blurs that will travel around the focal plane.

With respect to the scan mirror scatter, Slater inquired who set the specifications on the mirror. Pagano stated that he did but at the time he did not take into consideration doing radiometry within 2 km of a cloud. Waluschka stated that for the scan mirror, we do not know the near field mirror scatter, even with the number measured by TMA which is within 0.2 degrees of specular.

With respect to the Spectral / Scatter Measurement Assembly (SSMA), Ed Knight inquired whether the set of reticles that were used in the MODIS Ground Based Calibrator (MGBC) will still be used. Pagano stated the MGBC reticle approach has been replaced by the SSMA reticles.

3.5 Effect of Replan on Test and Calibration

Pagano presented information on the effect of the recent replan on MODIS testing and calibration (see Attachment 9). Pagano first stated that all critical EM testing has been preserved. Waluschka asked if the MGBC has been eliminated. Pagano replied negatively, stating that it will be used with the protoflight model but not with the engineering model. Pagano presented an overview of the MODIS test and calibration activities. He stated that a full test on the blackbody is planned. Ed Knight doubted that there will be enough time in thermal vacuum for a full checkout of the blackbody. Maxwell inquired whether scan angle dependent mapping will be done on MODIS. Pagano stated that yes, the rotational table has been re-implemented to do this mapping. Larry Goldberg asked if SBRC plans to make measurements of instrument optical transmission as a function of temperature. Pagano answered no. Slater then inquired if the plan is to do infrared calibration at one temperature. Pagano stated no, the external blackbody temperature will be varied.

With respect to the required tests for system level calibration and characterization, Slater inquired how much better the Integration and Alignment Collimator (IAC) is than the SRCA for determining the MTF. Pagano emphasized that the IAC will do much better in that it is a full aperture illuminator.

Concerning the Spherical Integrator Source (SIS) design, Pagano stated that due to funding limitations, SBRC would like to push the calibration of the integrating sphere into 1995.

Concerning the blackbody calibration, Pagano stated that the blackbody calibration source was not completely black in that one can look into the source and see the back

wall. Biggar stated that if the reflectance of the blackbody is higher for infrared radiation as indicated in previous charts presented by SBRC, the blackbody will then perform worse in the infrared than the visible.

With respect to the SSMA, Pagano stated that the spherical mirror is 10 inches in diameter. Maxwell asked if the spherical mirror will blur the slit image. Pagano stated yes, the blur will be about 1 IFOV. Waluschka asked the meaning of super-polished. Pagano was not really sure what it meant.

Concerning the spectral measurements assembly, Phil Slater inquired how SBRC will check the wavelength integrity of the assembly. Pagano was not certain. Ed Knight pointed out that the double monochromator used here is the same that will be used in the MGBC.

With respect to the MGBC, Ed Knight again asked if the reticles were pulled out of the MGBC. Pagano answered that the transient noise and stray light reticles will not be used, while the MTF and registration reticles will be retained.

Concerning the IAC, Gene Waluschka inquired if the IAC will scan individual pixels. Pagano stated that SBRC will scan a reticle across the focal plane to see how well we are doing registration.

With respect to the stray light test configuration, Maxwell inquired on the magnitude of the output light from the integrating sphere. Slater stated that he is worried that the signal-to-noise might be too low to do this measurement.

Concerning the Dedicated MODIS Calibration Facility (DMCF), Dick Weber asked if the window between he MODIS and the SSMA will cause high scatter. Pagano stated that the SSMA will be used with and without the window. Maxwell suggested that the window be canted to avoid ghost reflections. Maxwell also inquired whether the blackbody calibration source could be operated at liquid nitrogen temperatures to enable a comparison with the space view source. Pagano answered that Jim Young is concerned about the repeatability of the blackbody temperature sensors if they are taken to liquid nitrogen temperatures.

Concerning the thermal vacuum timeline, Slater asked if there will be a pre-ship review. Weber responded that there will be a pre-ship review in the four days after the test data are ready. Maxwell inquired if SBRC plans to test the cross strapping of the electronics and whether they will validate all permutations of the electronics. Maxwell also asked if SBRC plans to spot check their calibrations at a series of temperatures. Barnes asked if a timeline has been formally presented for the thermal vacuum test. Pagano stated that SBRC is late with the timeline that was originally due at the CDR. Pagano stated that the reason for the delay was the participation in the replan activities. Maxwell asked if the thermal vacuum schedule reflects the possibility that problems will arise in the operation of the on-board calibrators in thermal vacuum. Weber stated that SBRC is under contract for two cycles.

The remainder of this session was dedicated to answering additional questions. Barker inquired if radiometric calibration as a function of scan angle will be performed. Pagano stated yes, in ambient. Biggar inquired whether the ghosting / stray light problem will vary as a function of scan angle. Pagano stated yes, but he did not know how much. Barker asked if there is any way the instrument induced on-orbit polarization can be validated.

3.6 Calibration of PC HgCdTe Channels

Larry Goldberg presented information on an approach towards calibration of PC HgCdTe channels (Attachment X16). In his approach, a quadratic fit is assumed at different instrument temperatures but the same detector temperature. Pagano asked that since we have a series of optics in MODIS, will each optic have its own term. Goldberg answered that a weighted average would be fine. Biggar inquired on the assumption of a quadratic fit. Goldberg stated that the function is not linear and is not really a perfect quadratic. Goldberg agreed with Biggar that the best choice of a basis function should be explored.

3.7 MAT Questions to SBRC (Reprise)

The review of SBRC's answers to the MAT questions was continued from the early morning.

3.7.1 SD and SDSM Questions

Concerning the ability to access the SD / SDSM radiometric models, Pagano stated that all the information is in the requirement specification, the radiometric math model, and the analyses of the SDSM and the screen. Mike Roberto and John Barker have copies of these materials.

With respect to the uncertainty of the transmission of the solar diffuser screen, Pagano was not sure. However, he did state that the screen will be designed in 1995.

Concerning whether the screen transmission will be measured, Pagano stated that he believes it will be measured; however, it also could be modeled.

3.7.2 Blackbody Questions

With respect to the question of the emissivity of the in-flight blackbody being measured as a function of wavelength, Pagano stated that it will be measured via a reflectance measurement approach. The total integrated scatter of the blackbody will be derived from measurements of the BRDF. Phil Slater asked if the actual blackbody or a witness sample was measured.

With respect to gradients on the in-flight blackbody and the placing of the temperature sensors, Pagano stated that the gradients are negligible in the ambient mode. Pagano referred the group to the blackbody analysis presented in the CDR package for details.

Concerning the possible problem of the sun entering the scan cavity at oblique angles, Pagano stated that the sun hitting the internal side of the sunshade would cause a radiometric error if scattered light were to land on the blackbody.

With respect to earth shine incident on the blackbody, Pagano stated that earth shine is incident on the blackbody and has a radiometric error of 0.5 percent assuming a temperature of 270 K. Stuart Biggar then asked about this effect over scenes such as Antarctica and cold clouds (i.e. 200 K).

3.7.3 Thermal Calibration Questions

Concerning the plans for SBRC to make any characterizations of the optics transmissions as a function of temperature, Pagano stated that there are no plans. Larry Goldberg asked if the hot case would be characterized. The sensor will be characterized at two or three temperatures.

Concerning the request to obtain the consent to integrate data packages from SBRC, Pagano stated that some of the requested information is not known and some is proprietary. Goldberg stated that he needs this information to characterize the detectors. Barker asked if this information will be available on MSAP.

With respect to the long-term detector stability data in the possession of SBRC, Maxwell asked how much of the detector dynamic range has been allocated for DC restore. Pagano answered that 10 percent has been allocated.

3.7.4 DC Restore Questions

Concerning how many bits will be included in the telemetry, Pagano stated that all bits will be included in the telemetry. Pagano also stated that the offset will be changed once per scan.

Concerning whether the DC restore will restrict the range of the single master curve for data calibration, Pagano stated that the DC restore will bring us to the baseline in the A/D. Every data packet will contain these data. Both the 6- and 8-bit data will be sent.

3.8 Action Items

The action items from this session were entirely in the form of requests for additional information or clarification of information from SBRC. Therefore, these requests for additional information are action items to Dick Weber and Bill Barnes of the NASA/GSFC MODIS Project. These items are as follows:

1. *Weber & Barnes*: In previous meetings, SBRC presented data on the emissivity of the blackbody calibration source (BCS) surface as a function of wavelength. These data indicated that the reflectance of the surface increased from the visible to the infrared. It was stated by SBRC at this meeting that the BCS was not entirely black and that the back wall of the BCS is visible to the eye when looking into the source. If the emissivity/reflectance data is valid, this would make the BCS an even worse blackbody than in the visible. This apparent conflict and potential problem needs to be examined. Respond by next MODIS Science Team Meeting.
2. *Weber & Barnes:* A question arose on how polished is the super-polished spherical mirror in the SSMA. Respond by next MODIS Science Team Meeting.
3. *Weber & Barnes:* A question arose on how SBRC plans to verify and maintain the wavelength integrity of the SSMA. Respond by next MODIS Science Team Meeting.

4. *Weber & Barnes:* The effect of earth shine on the in-flight blackbody was questioned. In particular, the effect on the blackbody of flying over scenes such as Antarctica and cold clouds at 200 K was questioned. SBRC stated that they can run MSAP with the earth temperature at 200 K to quantify the effect. Respond by next MODIS Science Team Meeting.
5. *Weber & Barnes:* A clarification was requested as to whether SBRC will measure the actual emissivity of the on-board and external blackbodies or will they merely measure witness samples of these blackbodies? Are these measurements as a function of wavelength? Respond by next MODIS Science Team Meeting.
6. *Weber & Barnes:* A question and several doubts arose concerning the availability of sufficient light from the integrating sphere to successfully perform the stray light test. Respond by next MODIS Science Team Meeting.
7. *Weber & Barnes:* SBRC still has not submitted a formal timeline for the thermal vacuum testing. There is significant concern surrounding the lack of time for thermal vacuum testing given the magnitude of the job. Respond by next MODIS Science Team Meeting.
8. *Weber & Barnes:* A question arose concerning the effect of scan angle on the magnitude of the stray light problem. Respond by next MODIS Science Team Meeting.
9. *Weber & Barnes:* A clarification was requested as to whether SBRC plans to actually measure the transmission of the solar diffuser screen. Respond by next MODIS Science Team Meeting.
10. *Weber & Barnes:* A question arose concerning the magnitude of the effect on the radiometric error incurred when sunlight hits the internal side of the sunshade and then is scattered or reflected onto the blackbody. Respond by next MODIS Science Team Meeting.

4.0 LAND DISCIPLINE GROUP MEETING

The MODIS Land Discipline Group Meeting, held on Thursday, May 5, at the Greenbelt Marriott, was chaired by Chris Justice. Present were Dorothy Hall, Alfredo Huete, Steve Running, Alan Strahler, Vern Vanderbilt, Zhengming Wan, David Carneggie, Simon Hook, Al Fleig, Ed Masuoka, Rama Nemani, Phil Teillet, Dave Shirey, Steve Ungar, and Eric Vermote. The minutes of this meeting were prepared by David Toll.

4.1 Land-Atmosphere Interactions

Yoram Kaufman summarized the Atmosphere Group's SCAR (Smoke, Cloud and Radiation) activities with possible involvement or links to MODLAND (MODIS Land Group). The Atmosphere Group will collect data over northern California in mid-September. The measurements will occur close in time with a NASA Space Shuttle mission. The atmosphere group has scheduled the ER-2 aircraft with the MODIS Airborne Simulator (MAS) for ten hours with tentative plans to add ten more hours. Justice would like to modify the flight lines to include land area coverage of the HJ Andrews LTER (Long-Term Ecological Research) and the Plumas forest site. Coverage of the OTTER Transect should be evaluated. Justice will contact Eric Vermote and Brent Holben for use of a sun photometer at the time of the MAS data collection.

MAS will undergo extensive calibration and sensor checkouts after conversion to a 50-channel instrument during the fall of 1994, likely resulting in a long delay in data distribution to scientists (~ six months). However, Masuoka said quick-look data will be made soon after data collection. The MAS fire channel will likely have calibration problems, especially from saturation at high surface temperatures.

A planning meeting for SCAR-C (California test site) will be held at GSFC this May 17. The Brazilian SCAR experiment in 1995 will require advanced planning by as much as 6-7 months due to international and administrative constraints.

4.2 ATBD Review

MODLAND discussed their ATBD plans and reviews. Reviewer comments are being compiled and addressed individually and are generally positive. There is a concern that many of the at-launch algorithms may be too complex. Most of the MODLAND products have alternative, simpler models as back-ups.

4.3 MODLAND Science Visuals

David Toll and Dave Shirey of MAST will assist MODLAND to prepare a science visual package that the MODIS Team may use. Steve Ungar will meet with Piers Sellers to discuss using a Landsat TM scene to show 250-m clouds versus those at 1,000 m to illustrate the cloud contamination problems (especially cumulus) addressed with 250-m MODIS data. Other topics include the use of well calibrated and geolocated data for assessment of change.

4.4 Data Products

There is currently some discussion on how much Level 2 and 3 processing can be supported by EOSDIS under reduced budget scenarios. One possibility is to have Level-0 and -1 processing completed by EOSDIS and higher level processing by the Science Team members (at SCFs) and then sent back to EOSDIS for archiving and distribution. This would permit scientists closer link to the processing and allow the rapid procurement of new computer technology. EOSDIS is constrained by a 3-year procurement cycle. Problems may arise from quality control, shortage of funding and time deadlines. Other intermediate approaches might be considered. Team members should address comments directly to Vince Salomonson. The merger of EOS data from different sensor systems also needs to be examined closely by the Science Team. Steve Running wants to ensure that global meteorological data will be routinely provided by EOS.

4.5 Test Sites

Running reported that 12 of 17 LTER groups have expressed interest in collaborating with MODLAND. Running will help coordinate a proposal to be turned in this summer between NASA and NSF. Additionally, Running will help coordinate activities between NASA and NSF. LTER personnel will provide links to MODLAND with field measurements, for example, on land cover, LAI (leaf area index), and NPP (net primary productivity). NASA will provide satellite aircraft imagery. MODLAND and Vermote plan to help set-up Sun photometer measurements to measure aerosol and water vapor optical depths for selected LTER sites. A proposal has been submitted to NASA HQ to

provide outreach to the LTER community on atmospheric correction.

Chris Justice, through the Landsat Pathfinder Global Land Cover Test Site Program, is working to extend the LTER sites for MODIS to represent global land cover. He is evaluating ongoing field programs that are data "rich" for possible MODLAND sites. There are plans to characterize selected global sites with local (e.g., site description, DEM, metadata, etc.) and remotely sensed (e.g., Landsat TM and MSS) data and disseminate data on 8-mm tapes for each site. The HJ Andrews LTER site will serve as a prototype.

4.6 MODIS Instrumentation

Ungar showed MODLAND summary viewgraphs on the status of MODIS radiometric calibration and geolocation accuracy. MODLAND generally liked the specified accuracies. Jan-Peter Muller expressed concern that the MODIS 250-m bands do not have as accurate a geolocation pixel fraction as the other MODIS bands.

Justice would like the MODIS Calibration Group to meet when the discipline teams are not also meeting so MODLAND representatives can also attend. Zhengming Wan (thermal) and Alfredo Huete (optical) will review calibration ATBDs from a MODLAND perspective. The radiometric saturation of the MODIS fire band remains a problem. SBRC and MCST would like any evaluations they can get from MODLAND.

4.7 EROS Data Center

David Carneggie provided an overview on MODIS data processing, topography, and 1-km AVHRR and ASTER data processing at the EROS Data Center (Attachment ?).

4.8 Topography

Justice reported that NASA HQ in conjunction with SWAMP and EDC DAAC personnel is attempting to have a special EOS meeting to develop a topographic data plan for the at-launch product for the EOS AM-1 platform.

4.9 ASTER

Simon Hook said Level-0 and -1 processing plans for ASTER data are still undergoing extensive planning. Additionally, the role of the United States and Japan in ASTER data processing is not yet determined.

4.10 BOREAS

Muller would like to see an improved aerial photography coverage of the BOREAS site. Muller will coordinate with Sellers on BOREAS topographic considerations and incorporation of the collection of ground control points through a GPS receiver.

Ungar said the 50-channel MAS will likely not be available for BOREAS this year. Instead, the 12-channel design will be used. MODLAND suggested deleting the 745-nm channel and using the extra bits for 10-bit data to the two thermal channels. In addition, having the MAS on the C-130 versus the ER-2 will permit changes to the detector gain before each flight to improve the dynamic range of the collected data. Ungar will continue to investigate the MAS configuration for the MODLAND team.

David Herring, of MAST, will work on an *Earth Observer* article of MODLAND BOREAS activities. He will also assist with spin-offs to more popular periodicals. He offered assistance on presentation materials for future MODIS Science Team Meetings.

4.11 Action Items

1. *Running*: help coordinate a LTER proposal to be turned in this summer.
2. *Remer*: look into MAS coverage for HJ Andrews.
3. *Cohen and Vermote*: look in to MAS coverage of the Plumas forest site.
4. *Strahler*: look in to MAS coverage of the OTTER site.
5. *Vermote and Holben*: coordinate Sun photometer measurements at the time of the MAS data collection.
6. *Shirey and Toll*: will assist MODLAND to prepare a science visual package that the MODIS Team may use.
7. *Calibration Group*: recommended to meet when discipline groups can attend.
8. *Wan* (thermal) and *Huete* (optical): will review calibration ATBDs from a MODLAND perspective.
9. *MODLAND*: attend the proposed topographic data meeting.
10. *Ungar*: investigate the MAS configuration prior to BOREAS and SCAR-C for the MODLAND and assist with calibration issues.
11. *Wan*: contact BOREAS administration regarding planned field data research.
12. *Muller*: interact with Sellers and other BOREAS personnel about ortho-photo and color-IR photo coverage of the BOREAS site.
13. *Herring*: will work on an *Earth Observer* article of MODLAND BOREAS activities.
14. *Running*: pursue weather data for routine use in processing at-launch products.

5.0 OCEAN DISCIPLINE GROUP MEETING

The MODIS Oceans Discipline Group Meeting was chaired by Wayne Esaias. Present were Mark Abbott, Otis Brown, Frank Hoge, Bob Evans, Dennis Clark, Ken Carder, Howard Gordon, Chuck McClain, Frank Muller-Karger, Michael Heney (SSAI), Phil Ardenuy (RDC), Vince Salomonson (occasional), and Locke Stuart (secretary).

5.1 Agenda and Introduction

1. ATBD Review and Products
2. Validation, Round Robin
   - VIS, IR
   - With EOS COLOR, other Sensors
3. EOS COLOR Mission Justification (include Land)
4. Deliverable Schedule with SeaWiFS Slip
5. Global Grids
6. MODIS Instrument Concerns
7. Budget Rescoping (private discussion)

Wayne Esaias presented the agenda and mentioned that budget rescoping should be done in a private session. Item 5 will address the concerns of Ed Masuoka.

5.2 ATBD Review and Products

Esaias stated that the oceans presentation at the Algorithm Theoretical Basis Document (ATBD) review would be an integrated presentation based upon the product flow diagram. Sea surface temperature (SST) may need to be treated separately. Esaias will be responsible for presenting the overview. The Oceans Group felt that further effort needs to be placed on defining the types and sources of ancillary data required by the ATBDs, and for calibration and validation efforts.

Salomonson voiced the opinion that the review process was a positive step and that the team members should view this as an opportunity to present their algorithms, examine the critiques, and discuss future plans / processes. Data volumes will probably be of some concern to the review panel.

Discussions of a number of individual efforts followed:

- Brown stressed that SST validation data need to be of high quality. Measurement of skin versus bulk temperature is a problem when accuracies better than 0.4 K are expected. Correcting for aerosols is an episodic problem of some substantial dimension.
- Gordon's work in atmospheric and aerosol correction was termed absolutely essential, and will rely substantially on a SeaWiFS heritage. Gordon presented his algorithm for SeaWiFS earlier in the week with very favorable responses from the SeaWiFS Project and radiative transfer scientists who attended.
- Clark's discussions focused on weaknesses in the validation process. His ATBD focused on pigments and chlorophyll. MOBY will furnish him a data set with which to begin working validation problems; he will explore a semi-analytical approach. Validation of organics versus inorganics is still a question.
- Carder commented on the lack of information available to the reviewers on the interdependency of data products. Flow diagrams will help. He is concerned with the calibration of subtropical versus high latitude data and suggested that ocean temperature may be a good indicator of where the algorithms should switch.
- Hoge reported that he so far has received one review. He identified the bands which will allow him to derive chlorophyll and phycoerithryn absorption. The variability of normalized phytoplankton absorption spectra coefficients is a problem.
- Abbott reported on receiving two reviews with no real criticisms. Marlin Lewis had suggested applying the algorithm over land. In its initial form, Abbott's algorithm is extremely simple. Surface data acquisition may be a problem; Carder feels that downwelling photosynthetically active radiation (PAR) would be available to Abbott if needed.
- Esaias reported receiving no comments, since he has not yet turned in his ATBD. However, Esaias will give a presentation to the Review Panel on his proposed algorithm. [The ATBD was submitted prior to the review, and he is awaiting written comments]. His chlorophyll-A product will need to be merged with COLOR and PM MODIS for long-term global coverage.
- Evans announced that he received two reviews. There were no criticisms of his match-up database. A question was posed by one reviewer on the lack of an aircraft

component (a budgetary issue). Validation of *in situ* data was questioned, with Evans reporting that he expects to receive validated data. The need for calibration from the solar diffuser was identified as critical to the validation of the MODIS data.

Discussions concluded with Esaias' showing a graph of the radiance at the top of the atmosphere based upon Gordon's model. There was an expression of satisfaction with Gordon's atmospheric correction. Gordon commented that he would be unable to do atmospheric correction where the NIR water leaving radiance is significant. Esaias stressed the need (in coastal areas) for the high-resolution bands to help resolve the higher spatial variability.

5.3 Data Volumes

While Evans will try to define data volumes, he will need help in defining cruise, aircraft, and ancillary data volumes. Correlations with SeaWiFS data volumes and products was discussed.

5.4 Ancillary Data, Validation, and Calibration

Format uniformity in data collection for the oceanographic community is important to facilitate the processing of the *in situ* and ancillary data, and no one is currently managing the effort of defining formats and assuring uniformity. The placing of large quantities of ancillary data in the DAACs is also of concern. The transition of data from SeaWiFS to MODIS and COLOR needs to be addressed; no funding to accomplish the tasks has currently been identified. The importance of SeaWiFS as a precursor data source to MODIS was mentioned and the cost of transition from a possibly delayed SeaWiFS to MODIS was considered. The need for validation was considered; this is an area wherein no planning has been done to date, except Brown's proposal for validating SST. Funding for the validation and round-robin efforts initiated under SeaWiFS will decrease in 1996 and it is expected that MODIS will need to pick up some of the cost for the effort at that time, or "spotty" data will be available as an information source for MODIS. Validation will become particularly important for MODIS in the months immediately following launch to verify the data products and that the algorithms are producing realistic results.

The sources of vicarious calibration for oceans data were discussed. There was some concern that MCST is not emphasizing oceans calibration sufficiently. Salomonson suggested that the Oceans Group should plan on doing their own vicarious calibration, and that the MODIS Characterization Support Team (MCST) effort would concentrate on on-board calibration. The Oceans Group promised to share its SeaWiFS experience in calibration with MCST in the hope that SeaWiFS methods can be adapted by MODIS. MOCEAN participation in MCST needs to be increased. It is difficult to accomplish much in the calibration precursor meetings; they are "standing room only", with too much confusion. The possibility of MCST signing up for responsibility for the round-robin calibration and comparison was mentioned. Data documentation was also discussed; under the current scenario documentation is sparse.

5.5 Data Processing and Product Production

Salomonson posed the question of how much computing should be done on the Science

Computing Facilities (SCFs) versus the EOS Core System (ECS). What should team members be processing, versus EOSDIS? In one possible scenario, the Central Data Handling Facility (CDHF) would be used for archiving and distribution, but processing would be done by the SCFs. If team members did the processing in their SCFs, they would need to consider QA and operators. The cost may increase, but there is a potential to get data processed much more rapidly; SCFs (mostly located at team member university facilities) can upgrade hardware much faster than government facilities. Esaias raised a concern about the high level of effort needed to coordinate processing of data in the DAAC, based on SeaWiFS experience with the DAAC performing only the archive and distribution role. Salomonson concurred that it would be important for the Oceans Group to have their own QA performed in the DAAC, rather than trusting the DAAC's "generic" QA. The need for (possibly extensive) reprocessing was addressed, and the question raised regarding where that reprocessing would be most efficiently done. Considerable discussion followed on the amount of reprocessing required by other programs (TOMS, CZCS), the complexity of the processing and the practicality of handling such a task at the SCFs or the Team Leader Computing Facility (TLCF).

5.6 Combined Data Products

Considerations for merging data from the two MODIS' (AM & PM) with each other, and also with COLOR were discussed. Merging is necessary in order to provide the global 2-day coverage required to address temporal variability in the ocean. Budgetary constraints were mentioned—this task is not included in the current budget, which is particularly true given the AM and PM differences. The possibility of a "blended" ocean color product and its difficulties of different sun angles and times of overflight was discussed, but Carder again cited lack of funding as a limitation on the activity. McClain mentioned that there is also currently a lack of a mandate to do so from the COLOR perspective. The problem of different results from different platforms and how some of this can possibly be related to the diurnal cycle of plants was considered. This is an area where experience with real data (trial and error) will be useful to define procedures.

5.7 Validation -- Round Robin (VIS, IR) with EOS COLOR, MERIS, and OCTS

Clark insisted that the SeaWiFS calibration and associated Round Robin *in situ* comparisons should be transferred to MODIS. Foreign instrument groups have not stepped up to contribute to the current SeaWiFS effort (although the Japanese OCTS and German MOS and GKSS groups participate), or begin one of their own. It is not within the purview of the MODIS Oceans Group to fund a cross-calibration effort with foreign (Japanese, ESA) sensors. Brown and Clark felt that MODIS round-robin requirements should be addressed to MCST and the EOS Project.

5.7.1 EOS COLOR Justification

Esaias showed a chart of radiometric sensitivity for SeaWiFS, MODIS, and CZCS. Abbott raised the possibility of one MODIS, with no PM follow-on, and questioned the loss to doing viable research. The possibility of relying on OCTS or MERIS in this situation was addressed. EOS COLOR is needed to answer the requirements of a major

part of the oceans community for frequent global coverage. McClain showed a chart of MODIS global coverage, then MODIS with COLOR. COLOR gives 1-km data globally, and tilts to get around sun glint. It will complement MODIS to give 2-day global coverage, versus 6 days with MODIS AM alone. Brown argued that 2- or 3-day coverage is not important in Case I waters, but coastal coverage in Case II needs more frequent coverage. McClain showed percent coverage per unit time considering cloud obscuration; there is 90 percent coverage in about 12 days with MODIS/COLOR; and MODIS alone requires about 30 days. McClain felt that coastal needs are the best argument for more frequent coverage. Abbott reminded the group that ocean eddies are also important. Brown and Evans felt that the Group must wait on SeaWiFS before rendering final judgment. SeaWiFS has the resolution, and may show spectacular pigment concentrations and a much more variable and dynamic ocean than has been perceived with CZCS at one-quarter the sensitivity.

Substantial discussion followed on the relative merits of MODIS, SeaWiFS, COLOR, MERIS, and OCTS. Data continuity through NOAA's adaptation of one of these research instruments to an operational sensor was a consideration. Data compatibility and comparison are problems that need to be addressed. The possibility of deselection of COLOR, in light of the possibility of foreign data buys and team investigations, was discussed. If NASA canceled COLOR, but failed to provide resources for active participation in other instrument research, the impact on the viability of the oceanographic community would be substantial.

Brown wondered if there were any SeaWiFS benefit to the Land Group. This is an issue in view of the launch failure of Landsat 6, and the marginal operational status of the current Landsats. Abbott suggested that Tony Janetos should be approached about using SeaWiFS for acquiring land data.

5.8 Deliverable Schedule with SeaWiFS Slip

Potential delays in the launch of SeaWiFS were discussed, and the impact on planned cruises and budgetary activities was identified as a problem. Substantial delay in SeaWiFS will cause substantial programmatic loss to the oceanographic community, and will impact the development of MODIS algorithms, which are currently structured to depend heavily on the SeaWiFS heritage. SeaWiFS will be a primary source of data for the development of the MODIS algorithms and these data are needed as soon as possible.

5.9 Global Grids

The Oceans Group suggested that Level 3 gridding at 9 km is practical and favor the modified ISSCP (SeaGrid) used for AVHRR SST Pathfinder and SeaWiFS; that Level 2 should be unremapped. Evans felt that Oceans will produce products at SeaGrid scale to satisfy science requirements, then can rescale to suit the Project requirements for a common grid, if required. Esaias suggested a global split at 180° longitude as discussed in Evans' definition of a day. If a single view of the Pacific is needed, two days could be sewed together.

5.10 MODIS Instrument Concerns

Some discussion ensued regarding additional risk acceptance as the costs escalate. A reliability of 85 percent over 5 years is a concern. Going from 95 percent to 85 percent was felt to be a serious compromise; and the proposal to use Grade B parts is considered a serious compromise for the savings incurred. Otherwise, the reductions were viewed as necessary compromises to keep MODIS out of trouble. Loss of calibration and stability information will raise alarms.

5.11 Budget Rescoping

This was largely a private discussion, led by Esaias. It was particularly noteworthy that a general spirit of cooperation prevailed, with substantial agreement on strategies in the event of further SeaWiFS problems, the jeopardy of COLOR, and future MODIS budget reductions. Priorities were discussed and a general consensus of "working as a team" with available resources was adopted. The need to carefully "meter" current costing was stressed. There was particular concern for the proposal to have the SCFs compute their own products; associated costs were not originally considered and substantial budget revisions would be needed. Augmentation from the NASA SR&T budget was recommended, with the Group carefully spelling out its goals and requesting additional support where needed.

Summary actions included a mandate to address MODIS, SeaWiFS, and COLOR as a combined research facility, to approach the Land Group regarding the use of SeaWiFS and COLOR, and to plan budget scenarios at an upcoming meeting in Miami, which was tentatively planned for the last week in July.

5.12 Future Oceans Science Presentations

It was determined that Otis Brown and Dennis Clark should report respectively on Sea Surface Temperature and MOBY.

5.13 Action Items

1. *MCST*: consider a separate meeting with Oceans to discuss calibration plans.
2. *Oceans*: further consider product production in the SCF, as opposed to EOSDIS.
3. *MCST*: consider the possibility of adopting the SeaWiFS round robin and extending to MODIS.
4. *Esaias*: confirm the arrangements for an Oceans Discipline Group meeting in Miami the last week in July.

6.0 FINAL PLENARY

The MODIS Science Team reconvened on Friday, May 6, in a Final Plenary Session, chaired by Vince Salomonson. This session began with a science presentation on MOBY (Marine Optical Buoy) by Dennis Clark, of the Oceans Discipline Group (see Attachment X17).

6.1 Initial MOBY Results

Clark stated that the major objectives of the MOBY campaign are to provide a

continuous time-series of high spectral resolution water-leaving radiances for quality assessments of Ocean Color Flight Instruments, and to characterize the bias of the derived pigment fields induced by the observational constraint of a sun-synchronous orbit by optically measuring the temporal variability of the phytoplankton.

Clark announced that MOBY was deployed in February 1994 off the west coast of Lanai, HI. There is a cellular antenna nearby to enable downloading of data via modem. The site was also chosen because the water clarity there meets the team's needs and the neighboring islands provide a natural lee from the winds which offers maximum survivability of the buoy. There is a port nearby where the MOBY team established an operations center. From here, the team can regularly service the buoy and check its calibration; and they can quickly retrieve it in the event of severe weather.

Clark showed viewgraphs of the buoy's mooring configuration and pictures of MOBY in the water. He showed the buoy in the aftermath of high seas and 70-knot winds—a solar panel was ripped off and the buoy was fouled with the mooring line. Also, only one month after deployment, barnacles are growing around the collectors despite the anti-foulant applied around them. The paint was also beginning to flake off.

Clark explained that every three months divers return to the site to check MOBY's calibration. They can calibrate the total system in about 5 hours by coupling underwater lamps to the collectors and shining a precalibrated beam of light into the collectors. Clark stated that MOBY data are normalized according to NIST standards. He showed some sample data of incoming solar irradiance.

6.2 ATBD Peer Review Preparation

Michael King gave an introduction to next week's ATBD peer review. He stated that although ATBDs were sent to an average of five reviewers, it is unrealistic to assume that the panel reviewers have read them. King stated that the panel review will be an open meeting; however, due to time constraints, the audience will not be permitted to ask questions. They may submit questions in writing after the review.

6.3 MODARCH Status Report

David Herring thanked the Team for their feedback and input during the first six months of MODARCH's (MODIS Document Archive) operation. Herring recognizes that there are still some problems with the system—such as the inability to print multiple pages quickly from the Macintosh client—but points out that MAST has been working closely with Excalibur Technologies to correct the problems. He reported that, subsequently, MODARCH has become a beta test site for new versions of the PixTex/EFS software. The Team's feedback has helped and will continue to help drive the refinement of the system.

Herring introduced Michael Heney, MODARCH System Administrator, to give the MODARCH status report (see Attachment X18). Heney reported that since beginning operation on Oct. 1, 1993, more than 2,000 documents (45,000 pages or 2 Gbytes of data) have been archived in the system. The system is being used by agencies and individuals worldwide, including the MODIS Team, ESA, JPL, USGS, NOAA, EPA,

CERES Team, and various universities.

Heney discussed "arcinfo", a utility he wrote that enables users to log in to MODARCH and gain greater access and use of the system's database. Addressing the printing problem, Heney stated that MODARCH can set up UNIX print queues for users enabling them to print much faster to their HP or Postscript printers. MAST is also upgrading the MODARCH system hardware for greater storage and processing capabilities. MAST is investigating other uses for the system, such as setting up a MODIS home page on the World Wide Web or providing a home for browse data.

Heney announced that MAST now has the EFS version 3.5 (beta) which is currently being evaluated. The new version includes page range print capability for clients, client APIs (Application Programmable Interface), and a client launch and land facility enabling clients to open documents stored in MODARCH in the document's native application. Heney expects the new EFS client to be distributed to the MODIS Team by July 1994.

6.4 Land/Atmosphere Corrections

Eric Vermote presented an overview of MODLAND's atmospheric correction activities to date (see Attachment X19). He said their goal is to prepare and validate the MODIS algorithm for atmospheric correction over land. Vermote listed their ongoing activities, which include work on the sun/sky photometer network, radiative transfer modeling, work on heritage data sets, and development and validation of an advanced processing system for AVHRR GAC-LAC data. Vermote stated that he plans to work on developing prelaunch aerosol global climatology using AVHRR data.

6.5 MERIS Status Update

Mike Rast gave a brief status update on the development of MERIS (Medium Resolution Imaging Spectrometer), being developed by ESA (European Space Agency). Rast stated that lately he has been contacting and exchanging information with MODIS Team members. He has accessed MODARCH and retrieved information from there.

He stated that the goals of MERIS are to provide bio-optical oceanography—primarily, to assess ocean surface optical properties and water constituents leading to phytoplankton biomass and productivity estimates via measurements of various pigment concentrations. Secondary goals include atmospheric monitoring, investigations of cloud and aerosol parameters, measurement of cloud top height and water vapor column content, and observation of land surface processes.

MERIS will provide global coverage from a sun-synchronous orbit and views the Earth in a pushbroom swath. It has only 15 spectral bands, but those are flexible and can be repositioned to incorporate new algorithm developments. MERIS can discern 30 different classes of pigment concentrations. Rast pointed out that MERIS doesn't view into the IR, so it is essential that the Earth Science community fly MODIS.

6.6 Options for Implementing a MODIS Volcano Alarm

Luke Flynn, representing Peter Mouginis-Mark and the volcanology IDS team,

discussed options for including a volcano alarm on MODIS (see Attachment X20). Flynn began his presentation with an overview of the ongoing work in volcanology. He showed images of lava flows and their corresponding spectral measurements. He also showed examples of MODIS-like images of lava flows and lava lakes.

Flynn stated that without a volcano alarm on MODIS, scientists will have no operational capability to catch an eruption before it actually happens. He hopes to implement a thermal alarm that will enable volcanologists to detect potential eruptions anywhere on Earth. He is also interested in studying the interactions between plumes of smoke and ash from volcanoes and the atmosphere. Flynn said that AVHRR can't provide the necessary alarm because it doesn't provide daily global coverage, nor is its resolution high enough in the 3.75-µm region.

Flynn proposed using MODIS Band 20 to detect hot targets during the day, and Band 6 or 7 at night. He stated that the only operational commitment needed from the MODIS Team is to implement their small algorithm to see fires; the remaining data processing can be done elsewhere. Adding a volcano alarm to MODIS will also require turning on Band 7 at night.

6.7 ASTER Status Report

Andrew Korb gave a status report on ASTER (Advanced Spaceborne Thermal Emission and Reflection radiometer). (See Attachment X21.) Korb stated that ASTER will provide a compilation of reflectance and emittance spectra of typical Earth surface materials from 0.4 to 14.0 µm. Korb noted that the U.S. ASTER effort is being led by Jack Salisbury of Johns Hopkins University, with participation by Zhengming Wan of the MODIS Science Team.

Korb said that ASTER is eager to cooperate with MODIS and provide data wherever useful. They would also like input from the MODIS Team as to what measurements MODIS would find useful. Kaufman responded that measurements on vegetation would be useful.

6.8 Calibration Group Summary Report

Phil Slater gave a summary report of the Calibration Working Group meeting (see Attachment 10). Regarding the Calibration Plan / Peer review, Slater said that the plan was judged to include an adequate number of accurate preflight, on-board, and vicarious calibration methods for the solar reflective range; however, it was considered weak in the thermal. The major weaknesses related to "a lack of focus"—the Level-1 production plan was deemed not well identified, and there is uncertainty due to budget cuts regarding what calibration inputs will be available at launch.

Regarding the MODIS scattered light problem, Slater stated that MODIS may not meet the transient response spec because stray light was not originally included in the stray light response as an error. The sources of stray light are ghosting, optical cross talk, electronic cross talk, and scatter from the scan mirror. This may affect radiometric accuracy in the presence of clouds. Slater concurred that the ghosting problem was mostly fixed with the redesign options. He said the crosstalk is marginal, but

measurement SNR is low so crosstalk is hard to quantify. He noted that the scan mirror is within spec, but the spec was probably not well written.

Regarding SBRC's testing program replan, Slater reported that the Calibration Group is concerned that the testing and validation schedule for both the EM and protoflight model (PFM) of MODIS may be too short. The preflight characterization of the PFM will not be completed until April 1996, which leaves too little time to modify the OBC hardware and/or algorithms should problems arise.

According to Slater, Paul Menzel is planning in-flight IR cross calibration work with GOES-8 next year. Menzel estimates that top of the atmosphere radiances should be available within 0.5 K, with a goal of 0.3 K.

The Calibration Group also has concerns on the blackbody calibration source (BCS)—it is reflecting in the VIS. Funding for the thermal transfer radiometers is uncertain, Slater observed, so there will probably be no measurements to verify the modeling of the radiance output of the blackbodies, thus introducing risk.

Salomonson said he had hoped the Calibration Working Group would address the relative balance between ground-based calibration and the utility and importance of on-orbit calibration. Given budgetary considerations, he asked, should we worry about that issue? Slater responded affirmatively, but that he could give a better, more complete answer Tuesday, after the Calibration Working Group Meeting.

6.9 MODLAND Summary Report

Chris Justice summarized the proceedings of the Land Group Meeting (see Attachment 11). He stated that regarding MODIS' instrument characteristics, MODLAND has been conservative concerning band selection. But, he stressed, MODIS is an improvement on its predecessors. For example, its daily coverage capability increases the possibility of obtaining cloud free images. Moreover, MODIS' 250-m resolution channels enhance the Land Group's ability to derive sub-pixel clouds, surface characterization, and change detection.

Justice announced that the Land Group will participate in the upcoming BOREAS campaign. Dorothy Hall has already acquired MAS ER-2 data on snow cover. MAS and POLDER will also be used on the C-130 in the upcoming BOREAS campaign. Additionally, SCAR-C flights might also include the Plumas and HJ Andrews LTER sites.

Regarding ATBDs, Justice reported no apparent major problems. MODLAND will hold a "post mortem" after the panel review.

MODLAND is discussing with Wayne Esaias and Gene Feldman the possibility of using SeaWiFS data as part of its prototyping efforts for producing land products. Ed Masuoka has assured Justice of SDST's cooperation in producing SeaWiFS data for generating land products.

6.10 Atmosphere Group Summary Report

Michael King reported that the Atmosphere Group met with MODLAND to discuss the upcoming SCAR-C campaign, scheduled for between Sept. 17 and Sept. 24. Yoram Kaufman has already scheduled 10 flight-hours on the ER-2 for MAS and possibly AVIRIS. SCAR-C will mark the first deployment of MAS with a 50-channel, 12-bit digitizer. King noted that the preamps will need re-setting after the BOREAS campaign, which may stress the instrument. The C131-A will fly the University of Washington's *in situ* instrumentation as well as King's Cloud Absorption Radiometer (CAR) for the campaign.

King announced that everyone from the Atmosphere Group has submitted beta software to SDST. The University of Wisconsin uses McIDAS (Man-computer Interactive Data Access System) extensively; however, it does not use HDF (Hierarchical Data Format).

King reported that the Atmosphere Group is in good shape going into the ATBD reviews. The cloud mask software will be modified over the next few months to include the MODIS channels missed initially.

6.11 MODIS Cloud Mask

Paul Menzel reported on his coordinated efforts with the CERES Team and John Barker to develop a MODIS Cloud Mask. He said he will provide the team with an algorithm from which they may make their own cloud mask—there is no single, correct cloud mask, it simply depends upon one's definition of a cloud. Specifically, Menzel said his mask will indicate whether the FOV has an unobstructed view of the Earth's surface and whether the FOV is affected by cloud shadows. Attachment 13 explains Menzel's plans for the cloud mask in detail.

6.12 MOCEAN Summary Report

Wayne Esaias summarized the proceedings of the MOCEAN Meeting (see Attachment 14). He stated that the budget situation is becoming critical. He feels MODIS must re-examine Team member efforts, interrelationships, and priorities. There have been "hits" to MOCEAN's validation and calibration efforts. The Group has tentatively scheduled a meeting July 25-28 to begin developing a 5-year operating plan with milestones.

Esaias reported that the Ocean Group members are comfortable with their ATBD reviews and feel that the criticisms were constructive. The delivery of software to SDST will be impacted by the slip in the SeaWiFS launch date to January 1995. The original plans for the Group's VIS algorithms will need some adjustment. Esaias said there are no MODIS instrument concerns, except that there may be further descopes.

According to Esaias, EOS COLOR will fill a critical role for global coverage frequency.

Esaias said that the validation/calibration round-robins require special attention. There is still a need for an implementation plan for IR instruments. He is satisfied with the ISCCP 9-km grid used by the AVHRR Pathfinder.

Esaias encourages broader consideration of the use of SeaWiFS observations by other disciplines as appropriate.

6.13 Conclusions

Vince Salomonson concluded the Science Team Meeting by stating that he has two concerns: 1) ATBD peer reviews—he would like a summary of the results of the panel review; and 2) The Team needs to think aggressively about normalizing what has been accomplished to date, such as atmospheric corrections. He stated that different approaches are being used and we need to compare them.

Salomonson advised the Team to read the Technical Team Minutes for information on data issues and interactions with EOS and the ECS. He announced that the next MODIS Science Team Meeting will be Oct. 19-21 at the Greenbelt Marriott.